Current status of roadkills in a major Highway in Korea

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Abstract

Construction of highways influences fragmentation and deterioration of wildlife habitat. It is inevitable to observe the death of animals that are killed by vehicles. Nonetheless, the cause and status of animal road kills has not been well studied, and this is the first attempted to analyze road kill along a major highway in Korea. A total of 860 individual road kills were collected on Joongang Highway during 1996-2003. Among them, Korean hare (*Lepus sinensis*) with the highest figure to taled 165 individuals (19.2%); raccoon dog (*Nyctereutes procyonoides*) with 146 (17.0%); Korean squirre (*Sciurus vulgaris)* with 56 (6.5%); Korean water deer (*Hydropotes inermis*) with 90 (10.5%); roe deer (*Capreolus capreolus*) with 26 (3.0%). Domesticated animals totaled 232 in dividuals (27.0%); domestic dog (*Can is lupus familiaris*) with 25, and domestic cat (*Felis catus*) with 207.

The raccoon dog and hare population was correlated (p=0.000) indicating th at they use habitat similarly along the road presumably in a predator-prey relationship. There was a seasonal difference with mortality rates increasing in spring through autumn and decreasing in winter . Mortality of large herbivores was analyzed separately due to the hazard they pose to motorist and indicated that water deer were more frequently than roe deer (p=0.001). The seasonal peak was different among the two species (p=0.015). Habitat characteristics among mountains, open areas (agricultural field and grassland, etc), and river were not significant (p=0.205) indicating road kills were not different among habitat types. However, the average road kills in mountain regions (mean =7.03) was higher than in open areas (mean =5.28). This study suggests that the consequence of an increasing number of road k ill can be reduced through mitigation by designing

artificial structures such as eco-bridges, fences along the road side, culverts under the highway which would reduce the number of wildlife entering onto the roadway.

Keywords: Korean hare, raccoon dog, roe deer, Korean water deer ,habitat fragmentation, large herbivores

1. Introduction

Construction of highways contributes to economic development through the improvement of living conditions and the expansion of social overhead capital. On the other hand, they affect water, soil, and air quality, as well as atmospheric phenomena. Highways also influence fragmentation and deterioration of wild life habitat (Mader, 1984; Benett et al, 1994; Trombulak and Frissell, 2000). It is inevitable to observe the death of animals that are killed by vehicles on roadways. Habitat barriers between habitat patches will further affect connectivity, and interfere with species mobility and dispersal (Brotons and Herrando, 2001). Traffic load on transportation infrastructures such as roads and highways often reduces the quality of habitat for mammals, birds, and amphibians through noise production and visual disturbance (Reijmen and Foppen, 1994; Forman and Alexander, 1998; Hels and Buckwald, 2001). Furthermore, species richness and diversity decrease, and bird abundance significantly declines along highway (Rheindt, 2003). One study of road kill has been carried out in South Korea in Gyeongsangnam-do province but only measured the total number of dead animals and did not identify species (Kim et al, 2001) .In other countries, there have been accomplished studies related to the causes of road kill. For example, animals killed by

public traffic in Mikumi National Park in Tanzania were measured (Drews, 1995). Bird occurrence was reduced in pine forest fragments associated with road proximity in a Mediterranean agricultural area (Brotons and Herrando, 2001), and the frequency of medium-sized mammal road kill in an agricultural landscape was estimated both in America (Fraser, 1997; Card et al, 2000; Hubbard et al, 2000) and in Europe (Madsen et al, 2002 ; Mysterud, 2004). Presumably, ecosystem aggravation may occur due to the construction of highways, but few studies have quantitatively measured road kill, especially in Asian countries. This study, for the first time, attempts to analyze road kill by various factors (species, year, season, opening date of highway, habitat fragmentation), along the recently opened Joongang Highway in the middle part of the Korean peninsula.

2 . Study areas and methods

2 .1. Study Area

Joongang Highway crosses the central portion of the Korean Peninsula from north to south. It starts at Gumho junction near Daegu and terminates in Chuncheon interchange (IC) (Fig 1). There are more connections between valleys using tunnels through steep mountains than on other highways in Korea (Korea Highway Corporation, 2003). Many sections pass steep mountains, for example, Mountains Taebaek, Chiak and Sobaek from Wonjoo to Youngjoo known as ‘Baekdudaegan.’ Most areas between Chuncheon to Wonjoo and Youngjoo to Daegu pass through open fields, farmlands and mountains which are 100 to 700 meters above sea level.

The flora of the central Korean peninsula is typical for a temperate climate with a vegetation community consisting of a mixture of deciduous forests and environmental conditions influenced by the warmer southern and cold northern regions of Korea (Yim and Kira, 1975). The major deciduous species are oak (Quercus mongolica, Qaccutissima) and Korean beach (Fagus crenata). The major coniferous species are Korean pine (Pinus koreiensis) and needle fir (Abies holophylla). Carpinus species are also dominant conifers.

It is difficult to survey animal distribution and mortality, in detail along the entire expanse of Joongang High way due to its length (281.61 km in total). Therefore, the analysis of road kill was only conducted on major highway sections (Geumho - Andong - Poonggi - Jeicheon - Man jong-Hongcheon - Chuncheon) through the years of 1996 to 2003 (Table 1).

2 .2. Methods

Joongang Highway opened in 1995 and the 281.61km total length was completed by 2001 (Table 1). Road kill were collected in the mornings after sunrise. As a result, the exact time of death was unknown during this study. When the road kills were found, the date and location were recorded. No traffic volume was collected during the study period. Road kill counts were used to determine mortality caused by vehicle on wildlife populations. These animals were classified as birds, wild mammals, domesticated animals, and un identified mammals. The road kills were sorted by species, year, season, opening date of highway section, and type of habitat characteristics after the

opening of the section to traffic. Road kills were examined based on the type of habitat types in Jeicheon - Chunch eon (station 281.51- 386.42 km) where the highest rates of road kill were observed (Table 2). In these sections, habitat characteristics along both sides of roads were classified into several categories (mountain- mountain, mountain-plain, mountain-river, plain-plain, plain-river, and river-river) based on habitat type within 500 m from the highway using a GIS map (Table 2). Habitat characteristics on either side (east-west) of the road were not separated.

For seasonal analysis spring (Mar-May), summer (Jun-Aug), autumn (Sep-Nov) and winter (Dec-Feb) were grouped and compared to determine the annual difference among road kills. Mortality rates of large herbivore were examined separately to assess the possibility of danger to drivers.

2 .3. Statistical analysis

The most abundant population of Korean hare (*Lepus sinensis*) and raccoon dog (*Nyctereutes procyonoides*) were analyzed with non-parametric one way ANOVA (Kruskal-Wallis test) based on the assumption that raccoon population is dependent on hare population for prey.

Seasonal difference was analyzed with ANOVA to see the differences among seasons. For large herbivores, statistical analysis was performed separately with ANOVA to see the difference in number of mortality and season between roe deer (*Capreolus capreolus*) and water deer (*Hydropotes inermis*).

For estimating habitat characteristics, three habitat types were analyzed with log- likelihood ratio to see the differences between road kills and habitat association. There were 6 categories: mountain-mountain, mountain-plain, mountain-river, plain- plain, plain-river, and river-river for the total 104.7 km from Jeicheon - Manjong - Hongcheon - Chuncheon with an accumulative 760 road kills. The expected frequency and observed frequency was compared with G-test for goodness of fit.

3. Results

3.1. Road kill by species

A total of 860 road kills were collected along Joongang Highway from Jan 1996 through April 2003. Korean hare had the largest number with 165 individuals (19.2%), followed by raccoon dog with 146 (17.0%) ; squirrel (*Sciurus vulgaris*) with 56(6.5%); water deer with 90 (10.5%) and Korean roe deer with 26(3.0%). Domestic animals totaled 232 individuals (27.0%); domestic dog (*Canislupus familiaris*) was 25, and domestic cat (*Felis catus*) was 207 (Table 3). The high proportion of large herbivores, Korean water deer and roe deer, brings concern for vehicle safety in Korea. Among the most abundant road kills, Korean hare and raccoon dog, mortality was compared with Kruskal-Wallis test and mortality between raccoon dog and Korean hare was significantly positive over the study period (F=300.51, df=1,6, p=0.000).

3 .2. Road kill by season

Road kills were analyzed to determine the relationship between mortality and season. Because the season was not recorded for 35 individuals, 825 individuals out of the total 860 individual killed animals were used. The number of road kill was relatively high in spring (Mar-May, n=216), summer (Jun-Aug, n=233), and fall (Sep- Nov, n=249) whereas winter road kill was the lowest (Dec-Feb, n=128) (Table 5). There was a significant trend among seasons (F-value=5.96, df=2, 11, p=0.022), which indicated that there was a seasonal difference among species mortality during the study period.

3 .3. Road kill of large herbivores

The seasonal difference between water deer and roe deer was compared, and there was a difference between seasons (Fig. 2, F-value=11.212, df=6, p=0.015) for both species, the highest number was in spring and the lowest in winter. The quantity of road kill for water deer (mean=7.5) was higher than that of roe deer (mean=2.2) suggesting water deer were more common along the road, resulting in a higher number of animals being killed. The mortality rates of water deer had two peaks, Jun and Dec, although roe deer had the highest peaks in May and Oct.

3 .5. Road kill by habitat characteristics

Jeicheon - Chuncheon (station 281.51 - 386.19km) is 37.7% (104.68km) of the total length of the highway. The number of killed animals collected totaled 860 individuals of which 760 individuals (88.4%) were used for the habitat analysis in th is section.

The habitat of mountain-plain was the longest at 38.8km; mountain-mountain was 37.4km, mountain-river 16.2k m; plain-plain 10.4km; plain-river 2.0km; and river-river 0.7km (Table 6). The habitat of mountain-plain had the greatest number of individuals with 296 (38.9%) followed by mountain-mountain with 263 (34.6%). This indicates that wild animals associated with mountain habitat were most influenced by the construction of roads. Average mortality was measured by the number of road kills per kilometer. The greatest rates were for mountain-plain and mountain-river, both with 7.7 individuals/km, followed by mountain-mountain with 7.0, and p lain-plain with 5.3.

Habitat type was determined based on the environment within 500m on both sides of the road. Habitat type was not significantly different (G-value =7.211, df =5, p=0.205). Animals near river habitats might find ways to avoid traffic possibly bridges associated with the waterway, or the habitat is presumably less fragmented than that associated with mountain areas.

4 . Discussion

Korean hare had the highest mortality rates during the study period. They usually are the most active on the roadside from the hours of 1800 to 0500 (Won, 1967) and are often observed in forests and open areas, thus, making them the largest population of the road kills. In the middle part of Korea, hare are active in transition zones in the forests and bushes along the roadside. Korean hare are usually found below 500m in elevation, the same elevation range as most highways, thus resulting in high mortality rates. Raccoon mortality was observed as the second highest rate. In the relationship between hare and raccoon populations, a comparison of the mortality rates for each indicated a highly significant positive relationship ($p=0.000$) among two populations. Considering the similar habitat of the two species, the raccoon presumably followed the hare populations both in the forests and along the road, thus resulting in a higher number of road kills.

Joongang Highway partially opened in 1995, and was completed in 2001. There were 193 individual animals collected on Jeicheon to Manjong (37.13 km) from 1996 to 2002. Road kills at Hongcheon to Chuncheon to taled 232 (24.57 km), and there were 302 animals collected in Manjong-Hongcheon (42.98 km) (Table 1). The northern part of Joongang Highway (Jeicheon-Chuncheon), represen ting the most mountainous region of Korea, had three sections with the most numerous road kill (760/860=88.4%).

Most animals in the region breed in spring and summer and year lings disperse in fall and win ter. Accordingly, high numbers of road kill were observed during the breeding season in spring and during the active dispersion of young wildlife born in summer (n=233) and fall (n=248), and the lowest was in winter (n=128). Animal activity along the road was of ten

observed in spring when they graze vegetation and in the fall, when animals feed along the road, eating residual products from agricultural harvest(Kim et al., 2001).

The number of road killed Korean water deer and roe deer showed an increase both in spring (Mar-May) and in autumn (Oct-Dec) (Fig 2). Roe deer inhabit forested mountains and hills and prefer bright habitats, avoiding dark areas (Won, 1967). Korean water deer live in cultivated land sand near forests during the springtime and spend summer near shaded riversides. Korean water deer often lie on the sunny banks near rice fields and move in to open areas in search of grains (Won, 1967). Continuous migration of Korean water deer might be correlated with the high number of road kills. Studies of deer populations in other part of the word have seen a similar trend: high peaks in spring (Mar-May) and are the lowest in winter (Dec-Feb). White- tailed deer (*Odocoileus virginianus*) and moose (*Alces alces*) are frequently struck by automobiles in May and June in northern Ontario (Fraser , 1997), as are red deer (*Cervu s elaphus*) during the summer in Nor way (Mysterud , 2004). White-tailed deer (Allen and Mc Cullough, 1976) and roe deer accidents in Denmark (Madsen et al, 2002) peak in the autumn.

This study did not directly measure traffic volume, but the results indicate different seasonal peaks among roe deer and water deer (assuming that the number of road kills implies population abundance during the season) (Mysterud, 2004). Differences in the seasonal peaks of May and October for roe deer indicate that these populations breed earlier than those of water deer. Roe deer become less active in winter because they live in habitat

associated with forests (Won, 1967). There is little known about the ecological characteristics of water deer, the population of which is limited to eastern China and the Korean peninsula. Water deer presumably are common around villages and agricultural areas. Consequently, their populations could be active late into the season.

In conclusion, this study is the first attempt to analyze road kills quantitatively in Korea and one of the rare studies in northeastern Asia. The long- term monitoring of road kill is important for determining the general trends that highways have on wildlife populations and provide some insights to the populations themselves. Raccoon dog and Korean hare mortality was correlated indicating that they reside in a similar habitat, presumably as a result of a predator-prey relationship. Mitigation through the use of fencing or construction of eco-bridges could be an important measure to reduce the mortality rates of wild animals (Benett et al, 1994; Leijn en and Foppen, 1994). Large herbivores require special attention due to the threat they pose to drivers. The peak seasons of mortality among the two deer species was different, indicating their habitat use pattern varies, mortality was more frequent for water deer than for roe deer. Habitat characteristics may not be important for mortality rates of animals, however, it would be beneficial to correlate the traffic volume and road kill in future studies.

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Table 1. Section name, length of the section and opening date of the Joongang highway from south to north, Korea

Section	Length of the section (km)	Opening date
Geumho-Andong	89.8	8-29-1995
Andong-Poonggi	35.6	9-16-1996
Poonggi-Jeicheon	51.53	12-19-2001
Jeicheon-Manjong	37.13	8-29-1995
Manjong-Hongcheon	42.98	8-17-2001
Hongcheon-Chuncheon	24.57	8-29-1995
Total	281.61	

Table2. Definition of habitat type, landscape and effect on animals

Habitat type	Landscape description	Effect on animals
Mountain	Trees and soils in upland forests, usually roads dissecting existing mountains	Forest animals not crossing roads
Open areas	Farmlands, highland and grasslands	Animals in open field trouble crossing the road
River	Streams and river channels	Riparian animals less troubled crossing the streams; Streams damaged due to construction of pillars, runoffs during

		heavy rains

Table3. Number of road kill animals, percentage, common name and scientific name of each species on Joongang highway from 1996-2003

Species		# of road kill	%
Rodentia	Korean squirrel (*Sciurus vulgalis*)	56	6.5
	Manchurian chipmunk (T*amias sibiricus*)	1	0.1
Lagomorpha	Korean Hare (*Lepus sinensis*)	165	19.2
Carnivora	Korean-Badger (*Meles meles*)	1	0.1
	Korean Mink (*Mustela sibirica*)	4	0.5
	Korean Racoon dog *(Nyctereutes procyonoides*)	146	17.0
	Small-eared Cat (*Felis bengalesis*)	2	0.2
	Domestic Dog (*Canis lupus familiaris*)	25	2.9
	Domestic cat (*Felis catus*)	207	24.1
Artiodactyla	Korean Water -Deer (*Hydrpotes inermis*)	90	10.5
	Korean Roe (*Capreolus capreolus*)	26	3.0
Subtotal		491	57.1
Birds[1]		64	7.4
Unidentified mammals		73	8.5
Total		860	100.0

[1]Fifty-seven birds were unidentified except Phasianus colchicus (2), family Accipitridae (1), order Strigiformes (2) and family Alcidae(2)

Table 4. Number of road kill animals by species in Joongang highway during 1996-2003

Species \ Year'		1996	1998	1999	2000	2001	2002	2003	total	%
Rodentia	Korean squirrel (*Sciurus vulgalis*)	-	-	1	8	28	18	1	56	6.5
	Manchurian chipmunk (T*amias sibiricus*)	-	-	-	-	1	1	-	1	0.1
Lagomorpha	Korean Hare (*Lepus sinensis*)	6	1	2	29	28	76	26	165	19.2
Carnivora	Badger (*Meles meles*)	-	-	-	1	-	-	-	1	0.1
	Mink (*Mustela sibirica*)	-	-	-	-	-	4	-	4	0.5
	Racoon dog (*Nyctereutes procyonoides*)	3	5	4	21	23	68	22	146	17.0
	Small-eared cat (*Felis bengalesis*)	-	-	-	1	-	1	-	2	0.2
	Domestic dogs (*Canis lupus familiaris*)	1	1	1	4	3	14	1	25	2.9
	Domestic cats (*Felis catus*)	5	1	7	23	33	115	23	207	24.1
Artiodactyla	Korean water deer (*Hydrpotes inermis*)	1	1	-	10	10	61	7	90	10.5
	Roe deer (*Capreolus capreolus*)	1	-	1	9	6	9	-	26	3.0

Birds[2]	–	–	1	8	4	47	4	64	7.4
Unidentified mammals	–	–	–	10	9	44	10	73	8.5
Total	17	9	17	124	145	457	91	860	100.0

[1]No data in 1997

[2]Data during Jan-April

Table5. Number of road kill animals by month on Joongang highway during 1996-2003

Species \ Season	Spring			Summer			Autumn			Winter			Total
	M	A	M	J	J	A	S	O	N	D	J	F	
Korean squirrel (*Sciurus vulgalis*)	1	4	0	4	6	6	10	7	4	0	0	2	44
Manchurian chipmunk (T*amias sibiricus*)	0	1	0	0	0	0	0	0	0	0	0	0	1
Korean Hare (*Lepus sinensis*)	25	13	6	15	15	8	12	26	19	3	4	14	160
Badger (*Meles meles*)	0	0	0	0	0	0	0	1	0	0	0	0	1
Mink (*Mustela sibirica*)	2	0	0	0	0	0	0	1	0	0	0	1	4
Racoon dog *(Nyctereutes procyonoides*)	17	5	7	16	5	9	20	19	15	4	7	14	138
Small-eared cat (*Felis bengalesis*)	1	0	1	0	0	0	0	0	0	0	0	0	2
Domestic dogs (*Canis lupus familiaris*)	22	13	15	30	18	11	23	10	22	6	11	16	197
Domestic cats (*Felis catus*)	0	0	2	5	3	2	1	5	2	2	2	1	25
Korean water deer (*Hydrpotes inermis*)	6	9	15	16	6	7	3	7	8	9	3	1	90
Roe deer (*Capreolus capreolus*)	1	2	8	2	1	0	1	5	4	2	0	0	26
Birds	2	6	5	13	15	7	1	2	7	2	3	1	64
Unidentified mammals	12	5	10	9	2	2	3	3	7	3	5	12	73
Total	216			233			248			128			825
	89	58	69	110	71	52	74	86	88	31	35	62	

Table6. Types of habitat characteristics, length of area(km), number of road kills and mortality rate(individuals/km) in the Jeicheon to Chuncheon

Habitat characteristics of both side of road	Lenth(km)	Number of road kill	# of road kills expected	Mortality rate (individuals/km)
mountain-mountain	37.4	263	279.5	7.0
mountain-plain	38.8	296	269.4	7.7
mountain-river	16.2	125	116.4	7.7
plain-plain	10.4	55	74.9	5.3
plain-river	2.0	15	14.4	7.5
river-river	0.7	6	5.0	8.6
Total	105.5	760	760.0	7.2

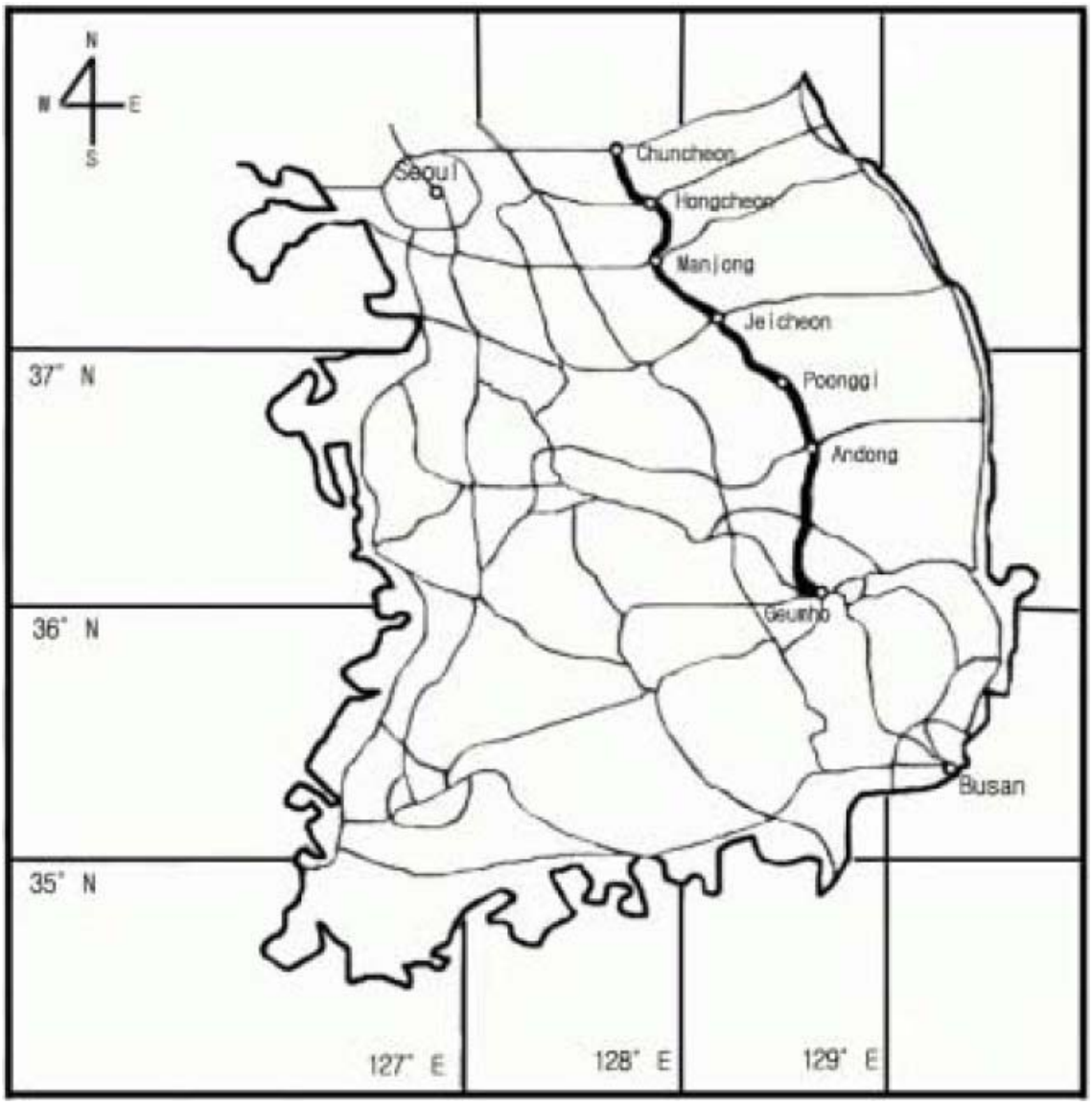

Fig. Map showing the highway system in South Korea. the Joongang highway is shown in bald line from Geumho-Chuncheon.

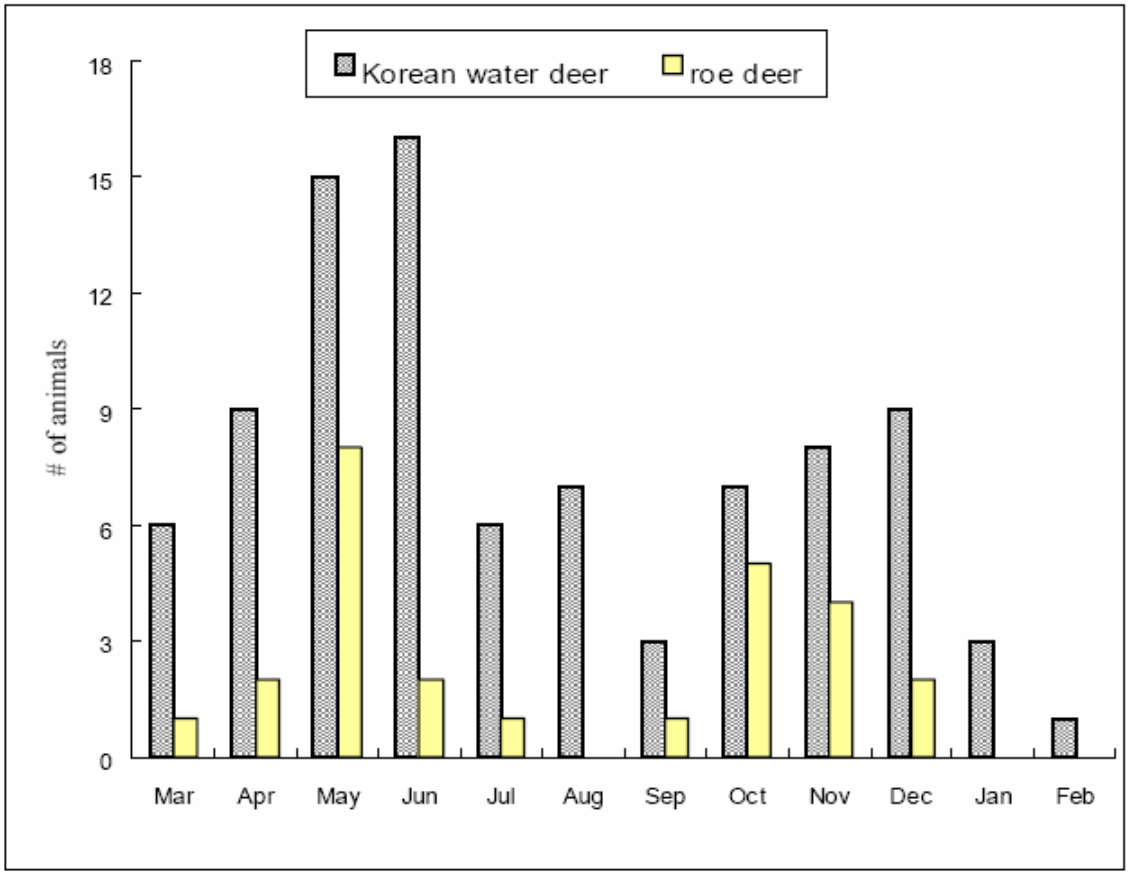

Fig 2. Road kill of Korean water deer (*Hydropotes inermis*) and roe deer (*Capreolus caprelus*) by month on Joongang highway during 1996-2003